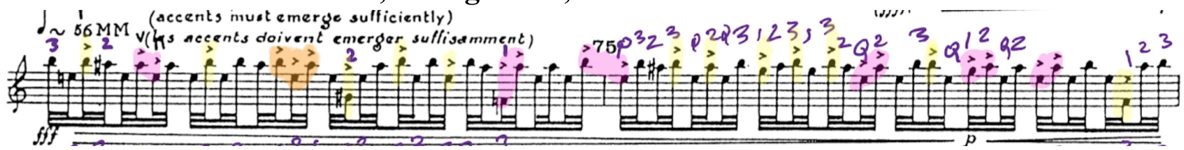
Personal, Background, and Future Goals Statement



It might seem strange to start an essay about my potential as a computer science researcher with a snippet of sheet music. On the surface, playing cello may appear to be completely different from researching program comprehension, software engineering, and computer science education. However, my twenty years playing and performing cello have instilled in me the creativity, determination, and passion for mentorship that shape and power my current research aspirations.

I believe that creativity, patience, and teamwork are all critical to success in both musical performance and impactful computer science research. In particular, I believe these skills are necessary to succeed at collaborative, interdisciplinary, and human-focused research. I find this research meaningful because it has the most potential to directly improve lives. In my doctorate and as a future professor, I will use the drive and curiosity I first learned through music to conduct research that breaks barriers and expands access for aspiring programmers from all walks of life.

"Any musical piece is akin to a boulder with complex forms… which can be deciphered in a thousand different ways without ever finding the right answer or the best one."   - Innis Xenakis

The snippet of music above is an excerpt from my copy of *Kottos* for solo cello by Innis Xenakis. Originally trained as an architect and engineer, Xenakis deliberately composed music with patterns and complex structure; a convincing and meaningful performance requires the musician analyze and decode these patterns to form their own unique framework for musical communication. While learning *Kottos*, I spent hours upon hours unpacking the intricate structure of the piece so that I could best transmit that structure and meaning to the audience. The excerpt above is indicative, full of my color-coded highlights that ground musical observations.

In my research, I apply the same creativity and curiosity that are emblematic of my approach to musical performance. As with music, analyzing patterns in large data sets requires constant creativity; there is rarely a single correct answer or pattern. Rather, the goal is to identify a consistent thread through the noise that reveals some new truth about the world. For example, I came up with the key idea behind my first published paper, *InFix: Automatically Repairing Novice Program Inputs*, by analyzing patterns in over 100,000 real student programming interactions. Through my analysis (and of course copious amounts of highlighting), I noticed that students fixed a non-trivial portion of their bugs by only modifying the *input* to their code rather than the code itself. Despite the prevalence of input-related bugs, all prior research that I found concerning novice debugging focused on the code and ignored input. As a result, students received limited support on input-related bugs, and I chose to focus my research efforts on this underserved area. My creative idea was to apply techniques from automated program repair to program inputs instead of the code itself. Overall, my pattern and data analysis led me to investigate a novel research problem that had the potential to help student programmers.

In research, as with music performance, it is imperative to continuously question your understanding. I believe that impactful research is rarely stagnant: proposed research foci and solutions change over time as the researcher broadens their contextual understanding. Constantly questioning my assumptions allows me to better navigate to the most important research topics.

For instance, one of my current studies involves testing how computer science undergraduates respond to various survey incentives. The idea behind this study came from questioning the methods I was using to recruit participants in previous studies. This research project is important because it will allow me to learn more about how to recruit the most participants given limited funds, therefore making future human-focused computer science research projects more efficient.

"I had to be industrious. Whoever is equally industrious will succeed equally well." - J.S. Bach

Kottos is the hardest piece I have yet performed. My approach to mastering *Kottos* exemplifies another key aspect of my personality that helps me complete large-scale research: relentless patience. While both music and research require ample creativity, the truth is that creativity does not lead to tangible results without exponentially more hard work. As an undergraduate cello major, for example, I routinely practiced a minimum of three hours a day on top of hours of rehearsals and additional music and computer science classes.

As a researcher, that same determination that pushed me through those long nights of practicing also lets me tackle large-scale computer science research projects. This is evident in my willingness to engage with manual annotations for noisy human-focused data. In the first year of my PhD, I designed and conducted three IRB-approved human studies of programmers, two of which have so far resulted in a peer-reviewed publication. From this experience, I learned that human studies require both organization and patience. The IRB process alone involves weeks of back and forth. Furthermore, as my studies involved qualitative data from anonymous participants such as Amazon's Mechanical Turk workers, it was necessary to manually inspect hundreds of submissions to assess response quality. While time-consuming, my manual effort produced a more complete understanding of the participants' experiences. In my opinion, to perform the most compelling human-focused research, the human experience must be front and center.

I also find patience essential for assessing the long term effects of research ideas. As such, I am willing to organize and conduct longitudinal studies where I can realistically measure the effect of my tools and interventions on programmers. In my research proposal, I outline a ten-week study investigating causal relationships between spatial training and computer science performance. While the study's formal launch is months away, I am already working on writing the IRB, applying for additional funding sources to pay participants, and collecting training materials. I also need to recruit participants, reserve rooms where participants can have weekly training, and organize participant compensation. I strongly believe, however, that all of this work is more than worth it; as both socioeconomic status and gender are highly correlated with spatial ability, finding transfer between spatial skills training and computer science performance has the potential to help thousands of aspiring programmers and to improve diversity in computer science.

"How could you have a soccer team if all were goalkeepers? How would it be an orchestra if all were French horns?" - Desmond Tutu

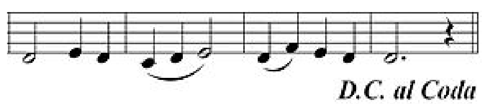
When I first suggested learning *Kottos* to my cello professor Anthony Elliott, his response surprised me. Rather than a simple yes or no, he told me a story that continues to shape my research goals. In 1967, Xenakis was starting as a Professor of Composition, and Elliott was one of the only black students in the classical music department. Elliott recounted how he faced constant racism from professors and other students, but Xenakis was different. Interactions with

Xenakis provided a meaningful respite from marginalization. Fifty years later, it was this respect that motivated Elliott to work with me for months on *Kottos* despite its musical challenges.

This story crystallized for me how environmental and systemic factors can influence an individual's perseverance, success, and relationship with their chosen career. With my own eyes, I have seen computer science struggle with a lack of gender and socioeconomic diversity. While my experiences are not the same as Elliott's, I have encountered situations in tech that make me understand why fewer women and minorities might choose to go into computer science. For example, after once describing an internship offer to a male colleague, he responded "wow, lucky you're a girl", attributing my success to my gender rather than intellectual merit. While I have evidence that this is not true, statements like this make me subconsciously doubt my own skills.

Both professor Elliott's and my own experiences show me that the relationship between systemic barriers and success is nuanced and complicated. I want to study it rigorously. I want to take ideas that have helped with diversity from other fields and apply them to computer science. In music, I have been active in community outreach through performances in underserved areas, leading cello lessons, and even mentoring at a women's prison in Alaska where I grew up.

In computer science research, however, I want to go beyond individual mentorship (which I have done, and certainly enjoy) to understanding, and ameliorating systemic barriers. My research could impact aspiring programmers who would otherwise feel unwelcome or be paralyzed by self doubt. My goals include building tools that support non-traditional novice programmers and investigating relevant environmental factors (such as spatial ability and socioeconomic status); I have concrete plans for a longitudinal intervention targeting spatial skills.



The skills and experiences I gained through music shape the computer science researcher I am today. With my interdisciplinary background, I bring a unique perspective that influences the questions I ask and the solutions I find. Ultimately, I will use my creativity, patience, and passion for equality to tackle human-focused research about program comprehension, education, and diversity. I conclude by summarizing my intellectual merit and broader impacts:

Intellectual Merit: My past work demonstrates that I can successfully design and conduct novel research. My *InFix* paper, for instance, is the first work to investigate and repair input-related bugs in a pedagogical setting. Furthermore, with my experience running multiple human-focused studies, I am well positioned to use rigorous statistical methods to evaluate the efficacy of my tools and interventions on programmers. As my research interests are at the intersection of software engineering, education, and psychology, I am able to use my own interdisciplinary background to collaborate effectively with researchers in these other fields.

Broader Impacts: Based on my own experiences, I deliberately choose to investigate research topics that can directly improve lives. Concretely, my two peer-reviewed publications both target increasing support for non-traditional novice programmers. I also have material plans for research that investigates systemic barriers, such as spatial reasoning or socioeconomic status, with the goal of making computing more inclusive and accessible. Finally, given the opportunity, I will use my creativity, perseverance, and passion for mentorship as a researcher, teacher, and future computer science professor to inspire and assist the next generation of computer scientists.